11th National Conference on Earthquake Engineering
integrating science, engineering, & policy

Automating Visual Data Processing to Support Post-Earthquake Reconnaissance

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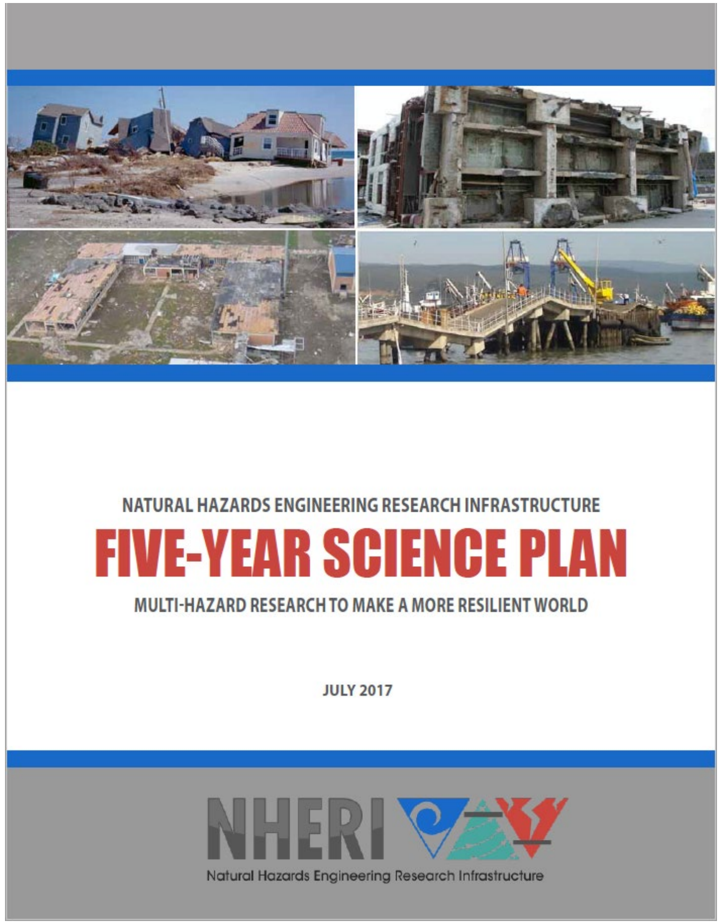
Motivation: NHERI Five-Year Science Plan



NHERI is the next generation of National Science Foundation (NSF) support for a natural hazards engineering research large facility.

KEY RESEARCH QUESTION # 5 in this plan

How can the scientific community collect and share data and information to enable transformative research and outcomes?

Develop regional systems to collect and analyze sensor and image information for use in planning, mitigation, response, and recovery.

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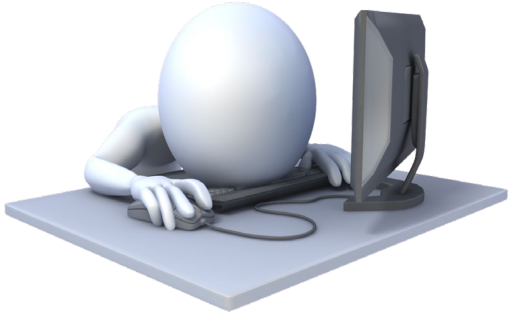
Key Idea: Automated Processing of Big Visual Data

A large collection of images after disaster



Various types, size, contents

Current visual data classification

Robotic platform

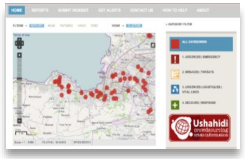
Satellite imagery

Smartphone

Google
flickr

Social media

Wearable dev.



Crowd sourcing

Various image collection platform

Processing

Computer vision

Autonomous image recognition

Collapse

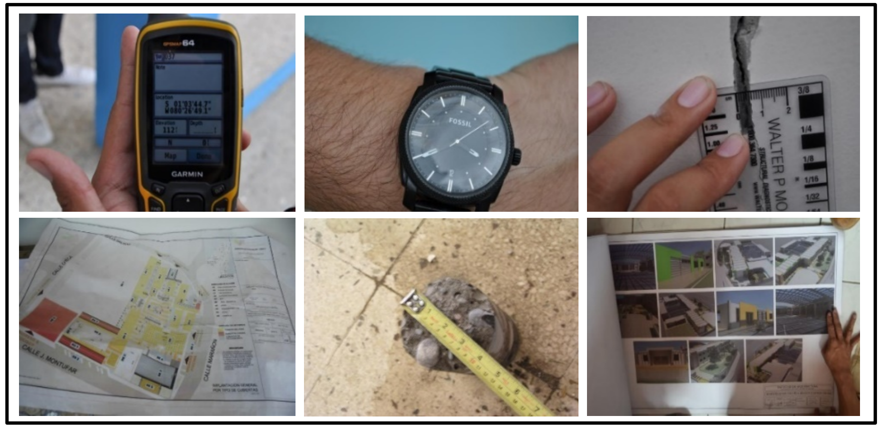
Spalling

New visual data classification

Post-Disaster Reconnaissance Mission

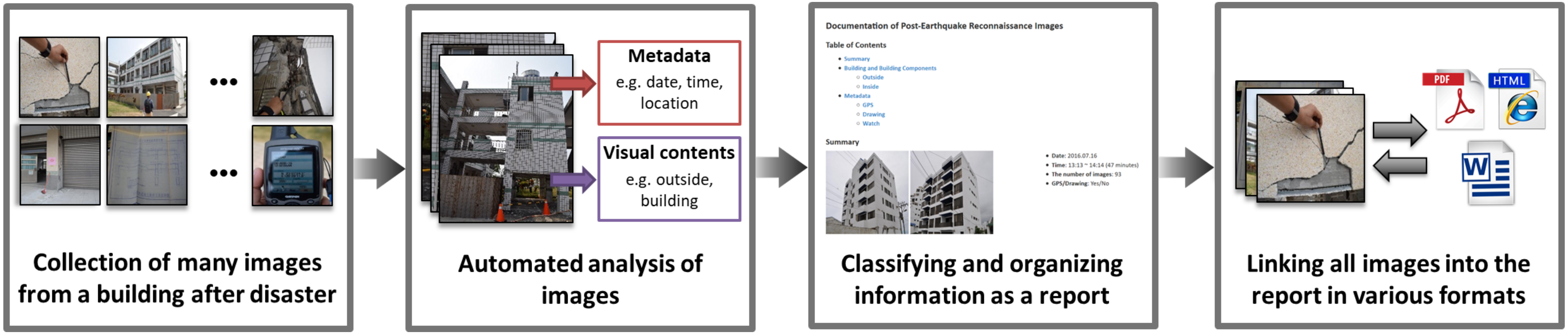
Reconnaissance mission (Taiwan, 2016)

Building and building components



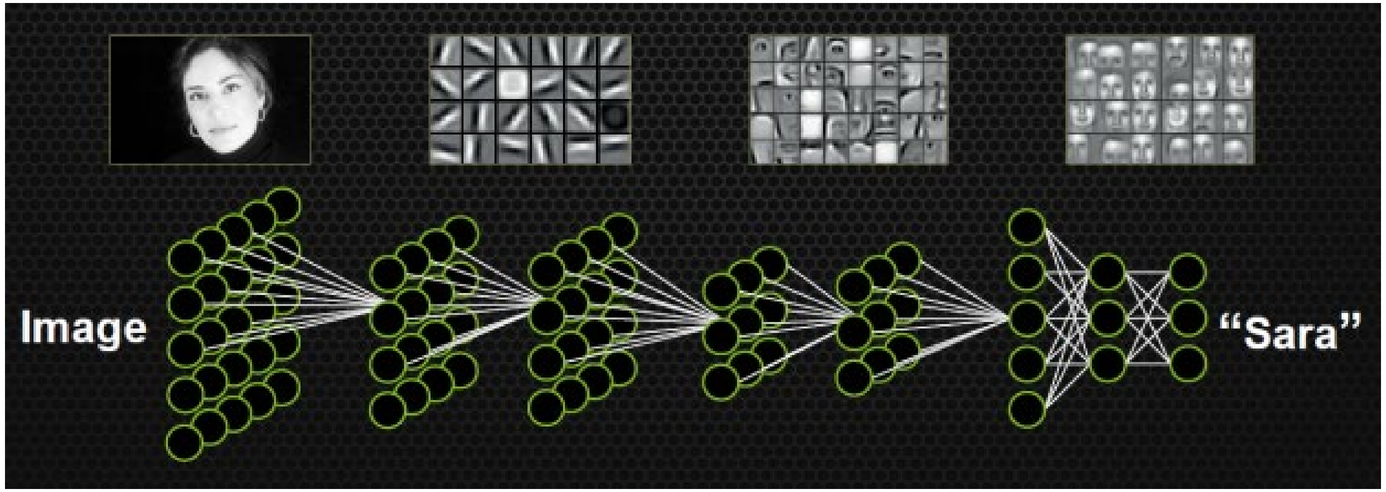
Metadata (recording information using images)

Automated Post-Event Reconnaissance Image Documentation

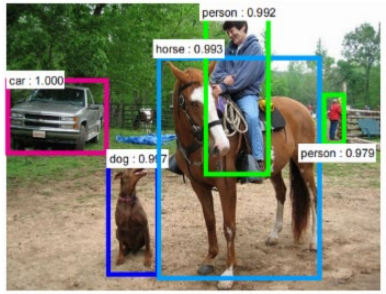


How to support field engineers to readily find and analyze images

Deep Convolutional Neural Network (CNN)



Convolutional neural network



Object detection

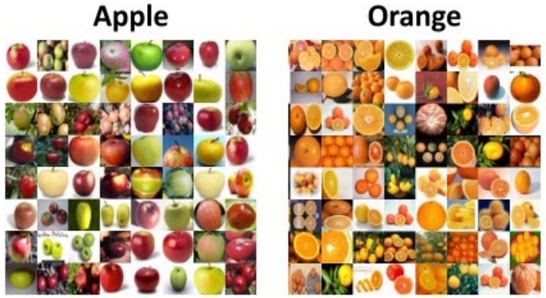
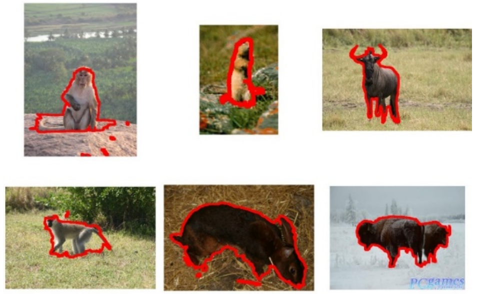


Image classification

Drone navigation



Object segmentation

Construction of Big Disaster Image Database

Taiwan earthquake in 2016 (14,102 images)

Nepal earthquake in 2015 (16,201 images)

Hurricane Katrina in 2011 (445 images)

Ecuador earthquake in 2016 (7,327 images)

L'Aquila (Italy) earthquake in 2009 (414 images)

Florida hurricanes in 2004 (1,178 images)

- **# of curated images: 85,000**
- **# of un-curated images: 490,000**
- **Total hours of reconnaissance videos: 10.5 hours**
- **# of event: 59 (EQ: 46, HR: 4, TN: 9)**
- **Image sources: datacenterhub, EERI, FEMA, CEISMIC, etc**
- **Current labeled classes: spalling, collapse, drawing, overview, etc**

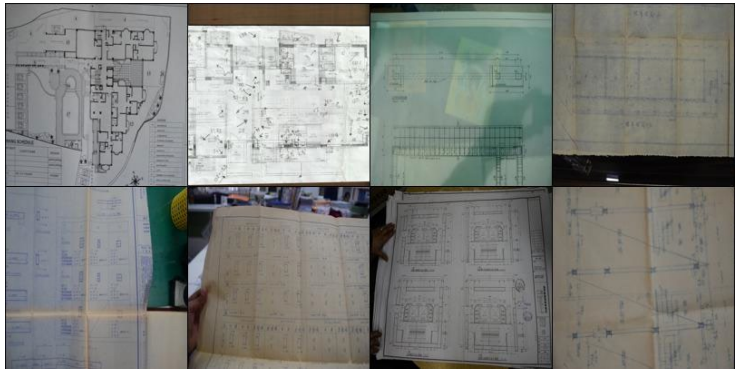
Designing Image Categories

Building overview

Measurement

Building exterior

Building interior



Drawing

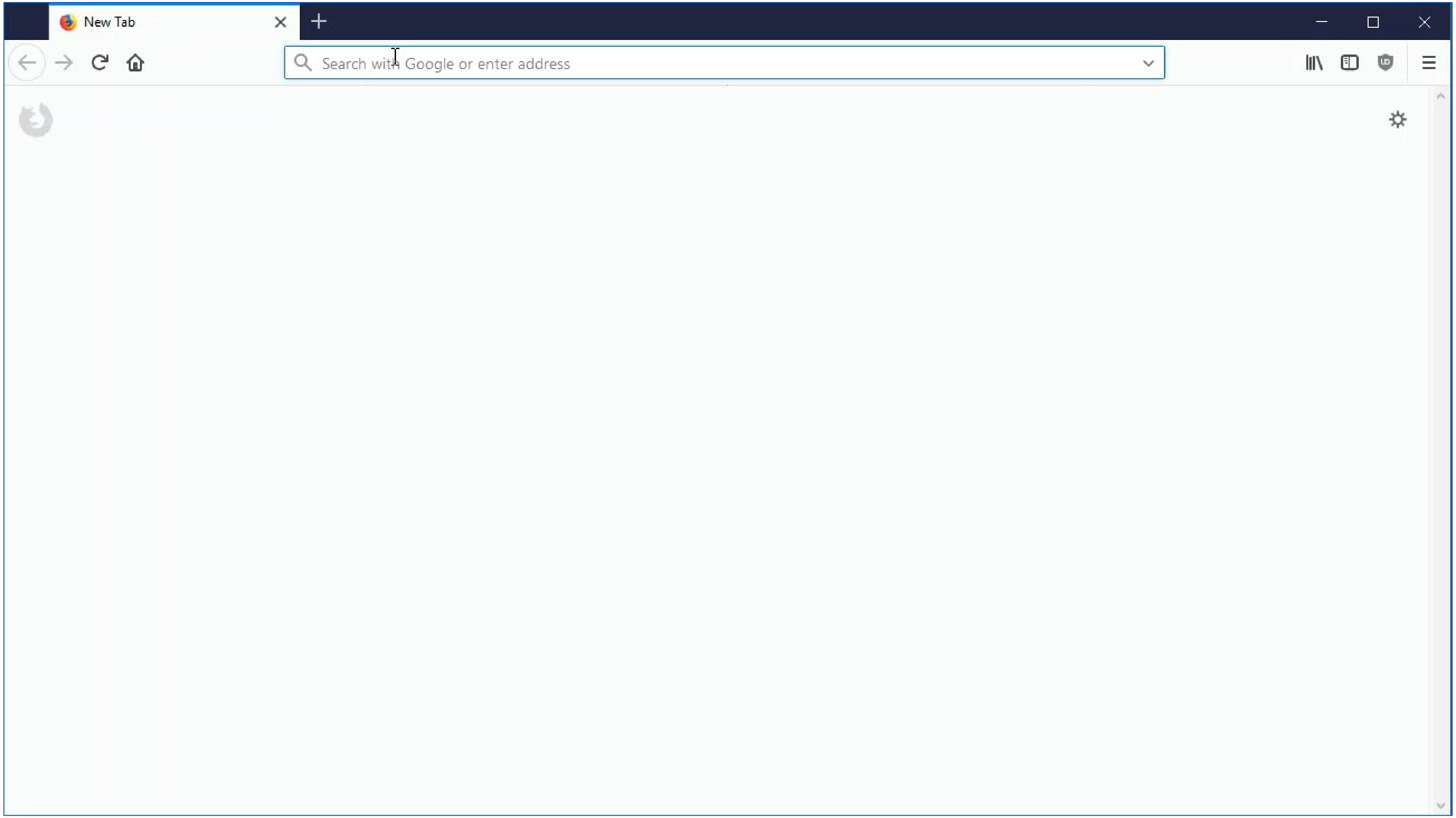
GPS navigator

Sample Report Generation (Ecuador, 2016)

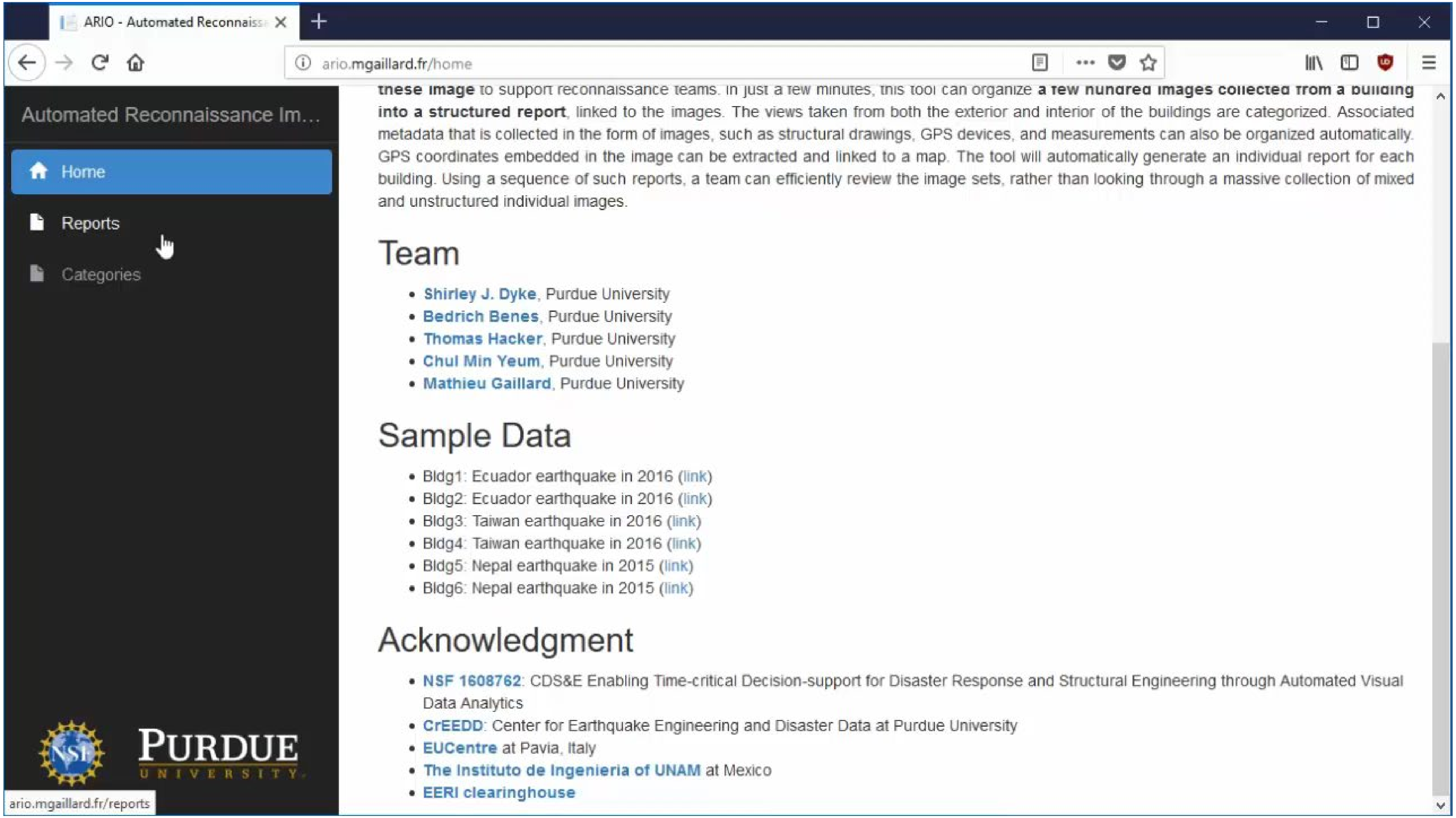
A sequence of the images collected from a single building

Building information

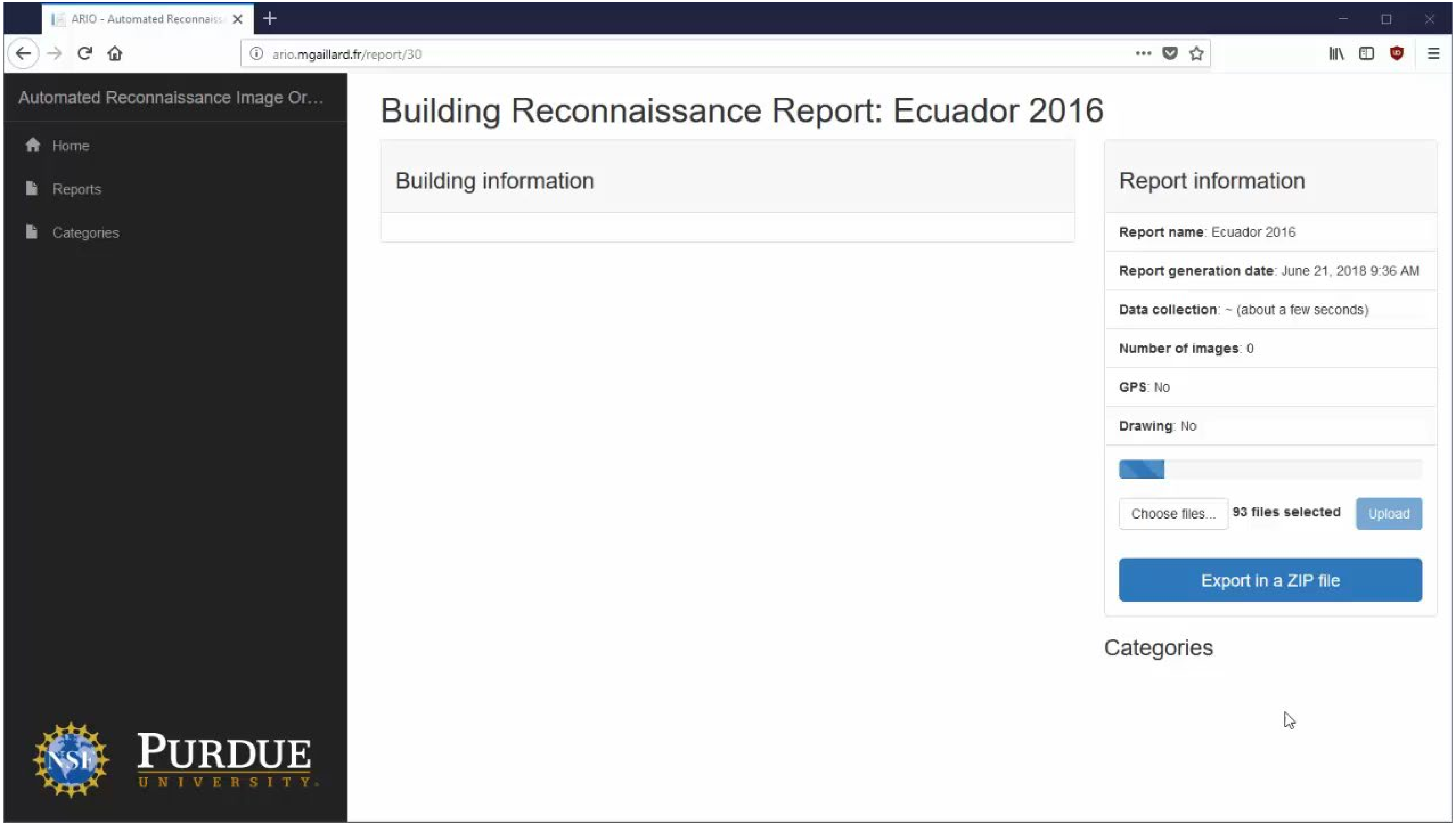
Event	Date	# of images	Structural damage	Masonry wall damage
Ecuador earthquake	July 16, 2016	93	Moderate	Severe



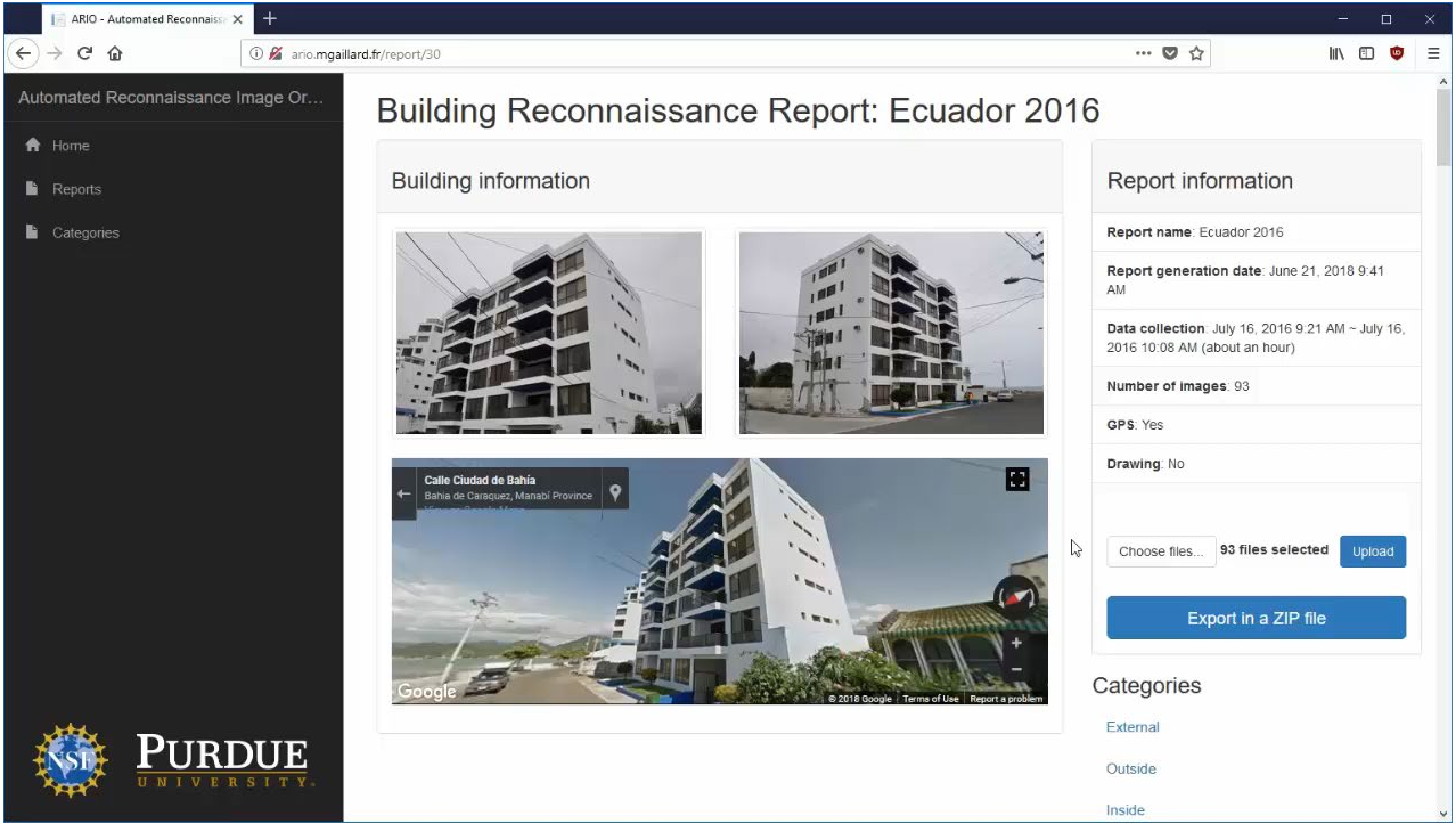
Automated Reconnaissance Image Organizer (ARIO)



Create a reconnaissance report



Review the report



Export the report

Potential Function 1: Earthquake Damage Recognition
Collapse Classification and Spalling Detection

Collapse

Image showing that the buildings or building components:

- lost their original shapes
- produce a large amount of debris

Spalling

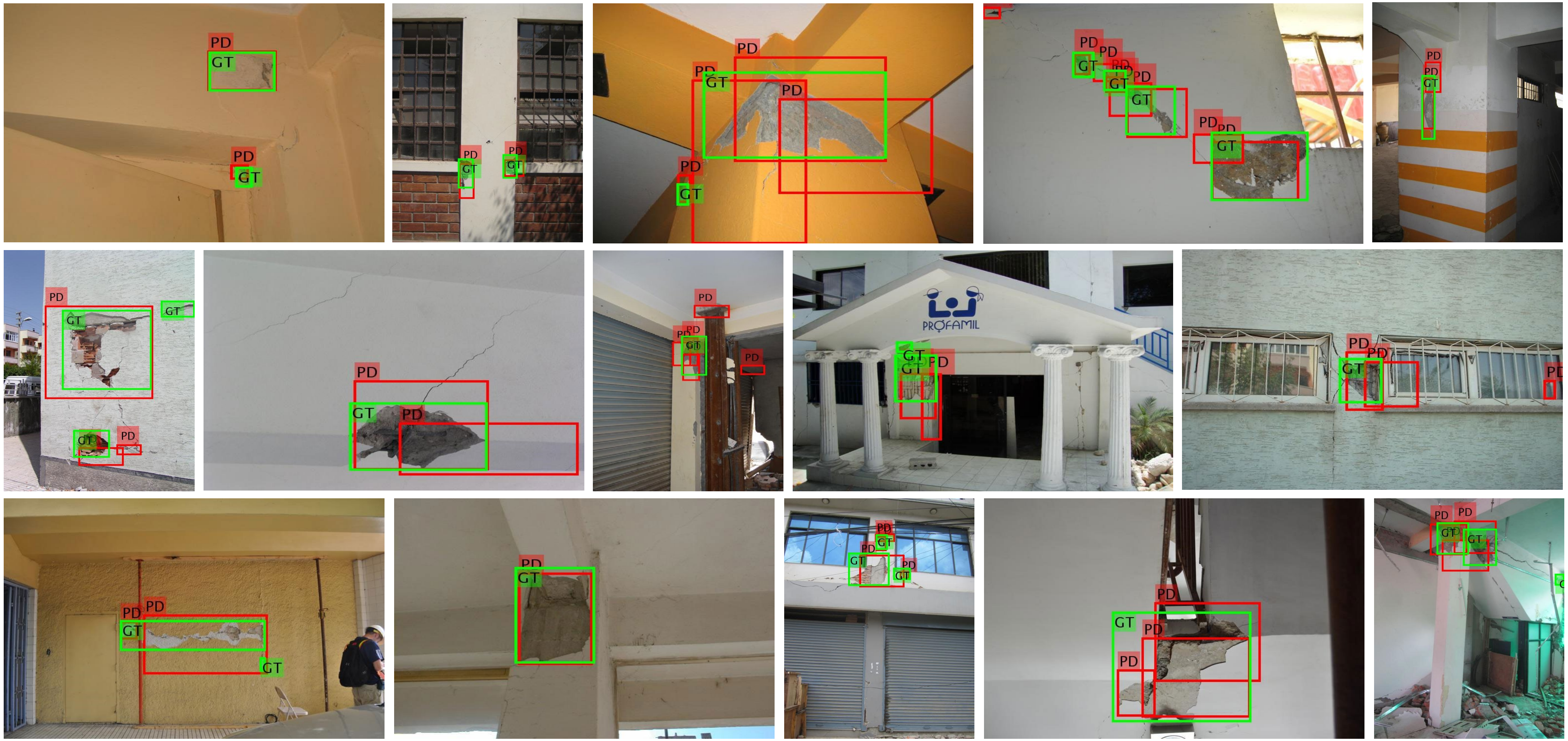
Image including

- exposed masonry areas in a wall due to cracking
- exposed rebar in a columns
- small section lose due to large cracking

Potential Function 1: Earthquake Damage Recognition

Sample of Collapse Classification

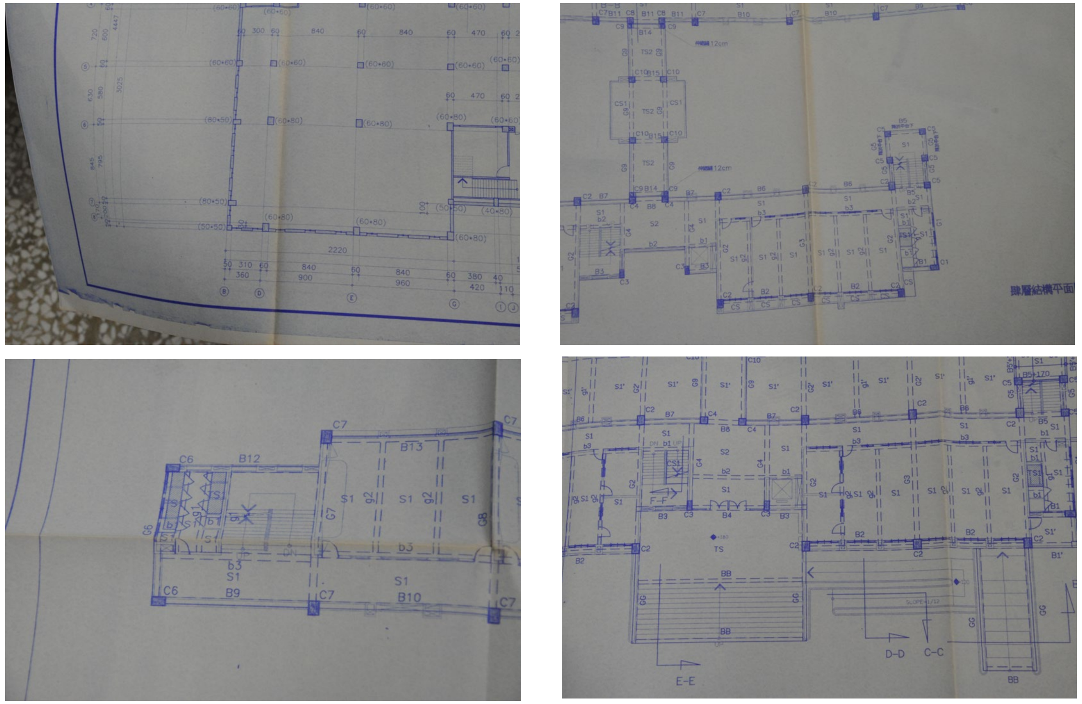
Potential Function 1: Earthquake Damage Recognition
Sample of Spalling Detection



Potential Function 2: Automated Recovery of Structural Drawing

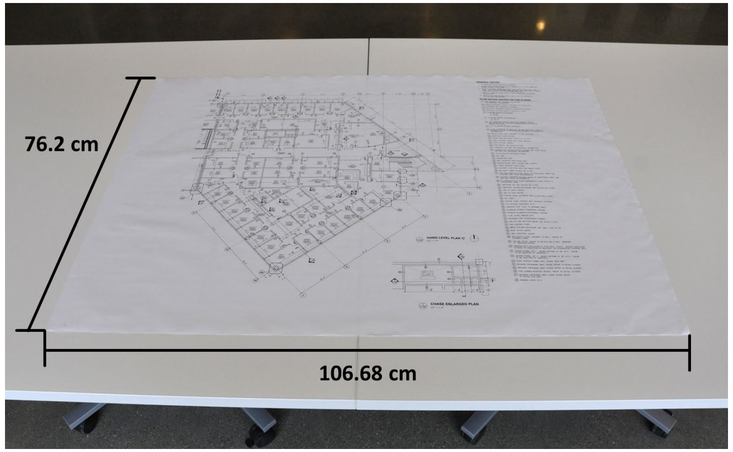
Collecting Partial Drawing Images during Recon. Missions

Images collected from a singe building after 2016 Taiwan earthquake



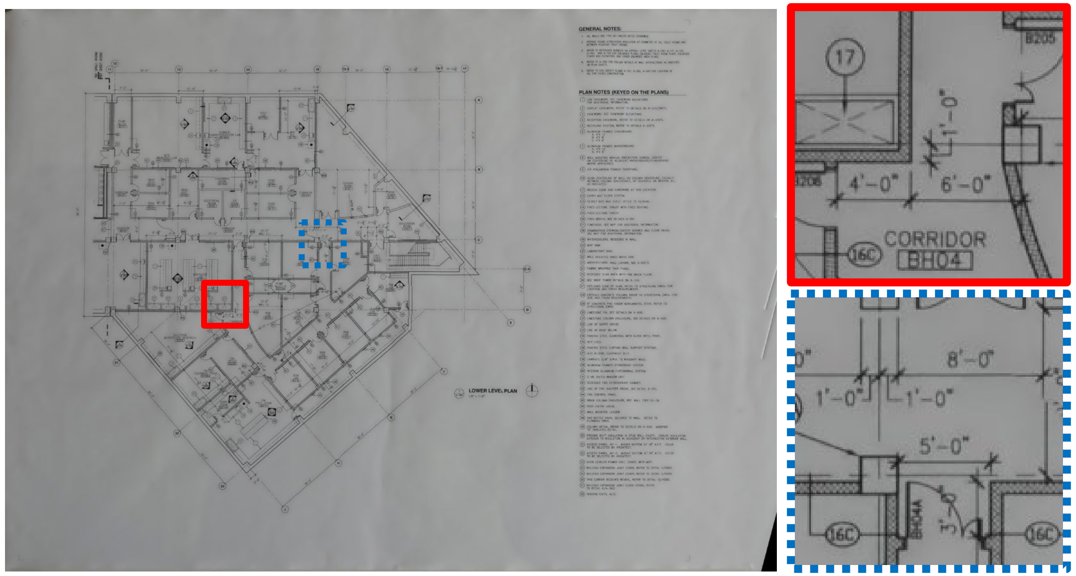
Sample partial drawing images captured from a drawing

Potential Function 2: Automated Recovery of Structural Drawing
Demonstration of the Developed Technique



Structural drawing printed on a large engineering paper

Partial drawing image captured from the original drawing



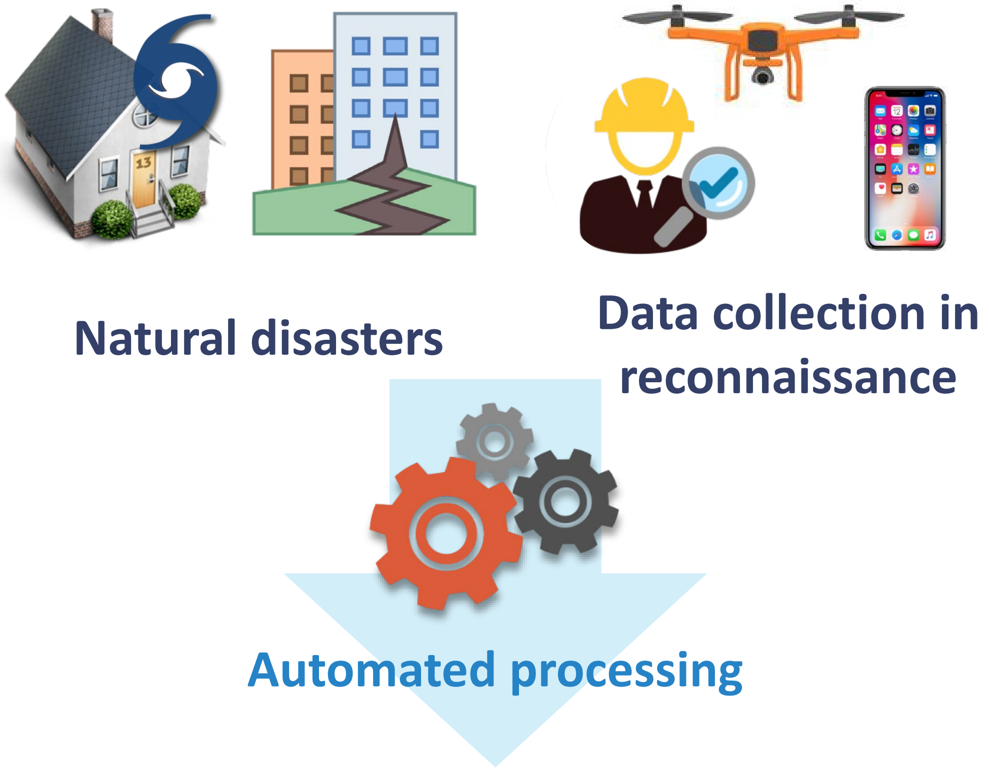
High resolution full drawing image

Conclusion

We developed a novel approach for rapidly and autonomously classifying and organizing post-event reconnaissance building images

As the use of drones and other data collection system increases, and more images are collected in future missions, automation will be essential to organize and understand the data.

We envision that our tool will support real-world natural hazard reconnaissance missions leading to safer infrastructure and more resilient communities.



- **Collect more valuable data in the field**
- **Understand gaps in structural design codes**
- **Mitigate potential loss in future events**

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Data Contributors

- CrEEDD: Center for Earthquake Engineering and Disaster Data at Purdue
- EUCentre (Pavia, Italy)
- The Instituto de Ingenieria of UNAM (Mexico)
- FEMA and EERI

Publications

- Chul Min Yeum, Alana Lund, Shirley J. Dyke, Julio A. Ramirez, "Automated Recovery of Drawings from Earthquake Reconnaissance Images," accepted to Journal of Computing in Civil Engineering (2018).

- Chul Min Yeum, Shirley J. Dyke, Bedrich Benes, Thomas Hacker, Julio A. Ramirez, Alana Lund and Santiago Pujol, "Post-Event Reconnaissance Image Documentation using Automated Classification," submitted to J. of Performance of Constructed Facilities (2018).

- Chul Min Yeum, Shirley J. Dyke, and Julio A. Ramirez, "Visual Data Classification in Post-Event Building Reconnaissance," Engineering Structures 155 (2018): 16-24.

- Chul Min Yeum, Ali lenjani, Shirley J. Dyke and Ilias Bilionis, " Automated Detection of Pre-Disaster Building Images from Google Street View," submitted to the 7th World Conference on Structural Control and Monitoring, China, July 22-25, 2018.

- Chul Min Yeum, Shirley J. Dyke, Bedrich Benes, Thomas Hacker, Julio A. Ramirez, Alana Lund, and Santiago Pujol, "Rapid, Automated Image Classification for Documentation," Proceedings of the 7th Conference on Advances in Experimental Structural Engineering, Pavia, Italy, September 6-8, 2017.

- Chul Min Yeum, Shirley J. Dyke, Julio A. Ramirez, Tomas Hacker, Santiago Pujol and Chungwook Sim, "Annotation of Image Data from Disaster Reconnaissance," Proceedings of the 16th World Conference on Earthquake Engineering, Chile, 2017.

- Chul Min Yeum, Shirley J. Dyke, Julio A. Ramirez, and Bedrich Benes, "Big Visual Data Analysis for Damage Evaluation in Civil Engineering," Proceedings of International Conference on Smart Infrastructure and Construction, Cambridge, U.K., 2016.

Questions and Answers